

# Measurement of Charged Antiparticle to Particle Ratios by the PHOBOS experiment at RHIC

Christof Roland (MIT)

for the

 **PHOBOS** Collaboration

# PHOBOS Collaboration

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# Why Measure Antiparticle/Particle Ratios?

- **Measured Quantities:**

$$\frac{\langle p^- \rangle}{\langle p^+ \rangle} \quad \frac{\langle K^- \rangle}{\langle K^+ \rangle} \quad \frac{\langle \bar{p} \rangle}{\langle p \rangle}$$

- **Baryon Transport**

- **Antiproton/proton ratio determined by:**
  - Baryon stopping;
  - Pair production;
  - Absorption in nuclear medium

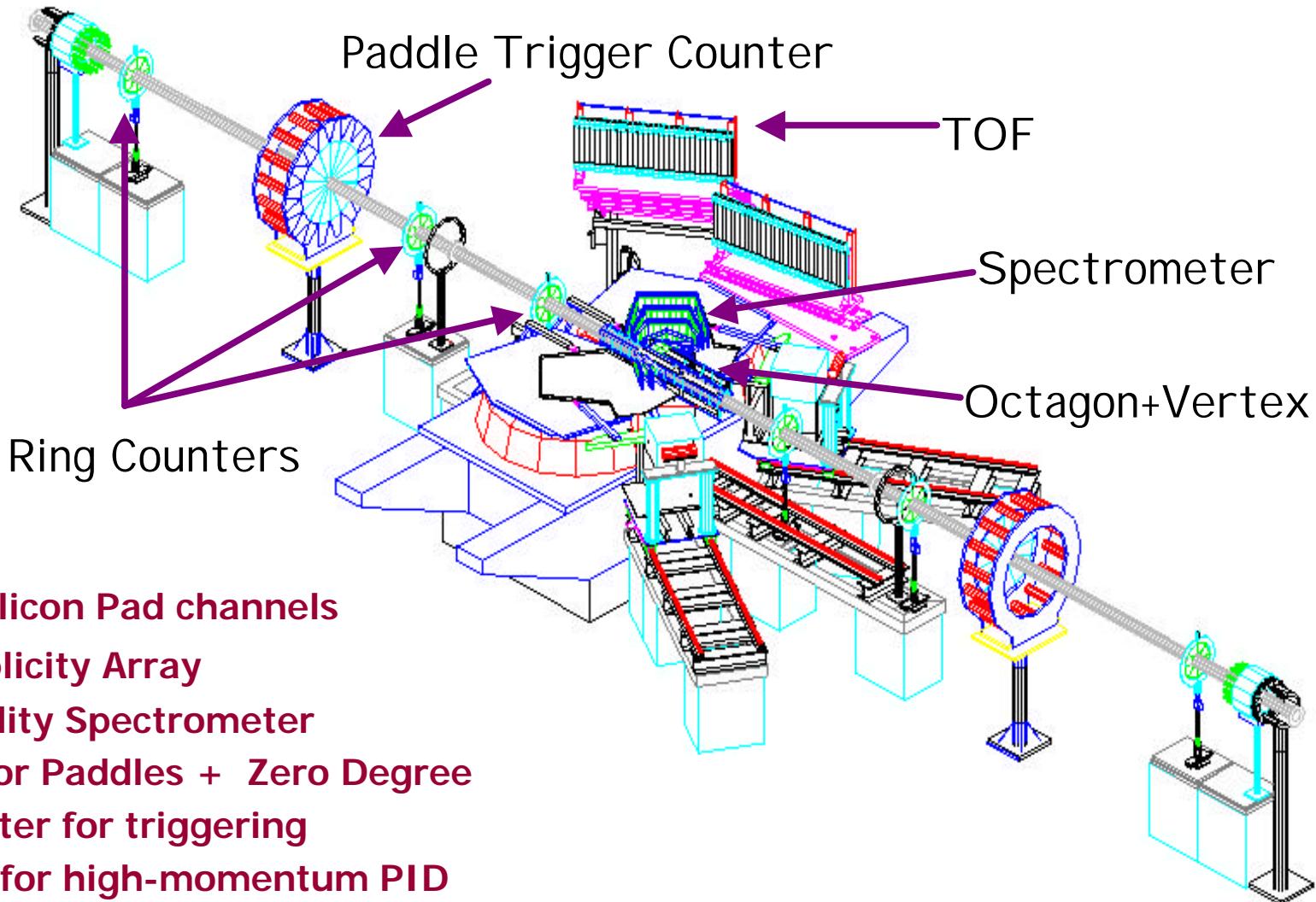
- **Hadron Chemistry**

- **Particle ratios can be used to estimate hadro-chemical potentials**

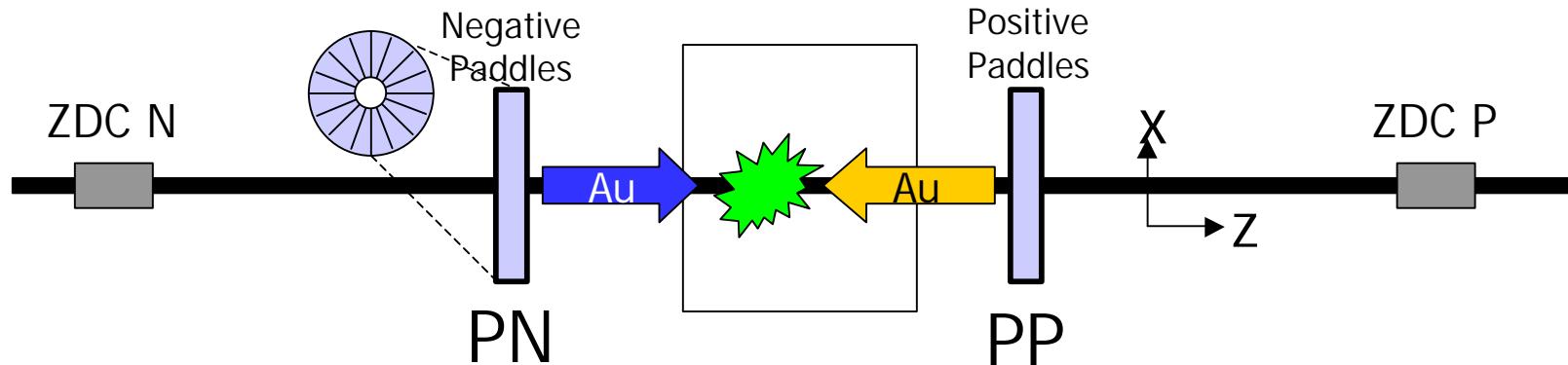
# Data Sample

- **Au + Au Collisions @  $\sqrt{s} = 130 \text{ GeV}$  (y2k)**
- **Vertex Range:  $-16 < z < 10$**
- **12% most central**
- $\langle N_{\text{part}} \rangle \sim 310$
- **~70000 events**
- **2 B-Field polarities**

# PHOBOS Detector

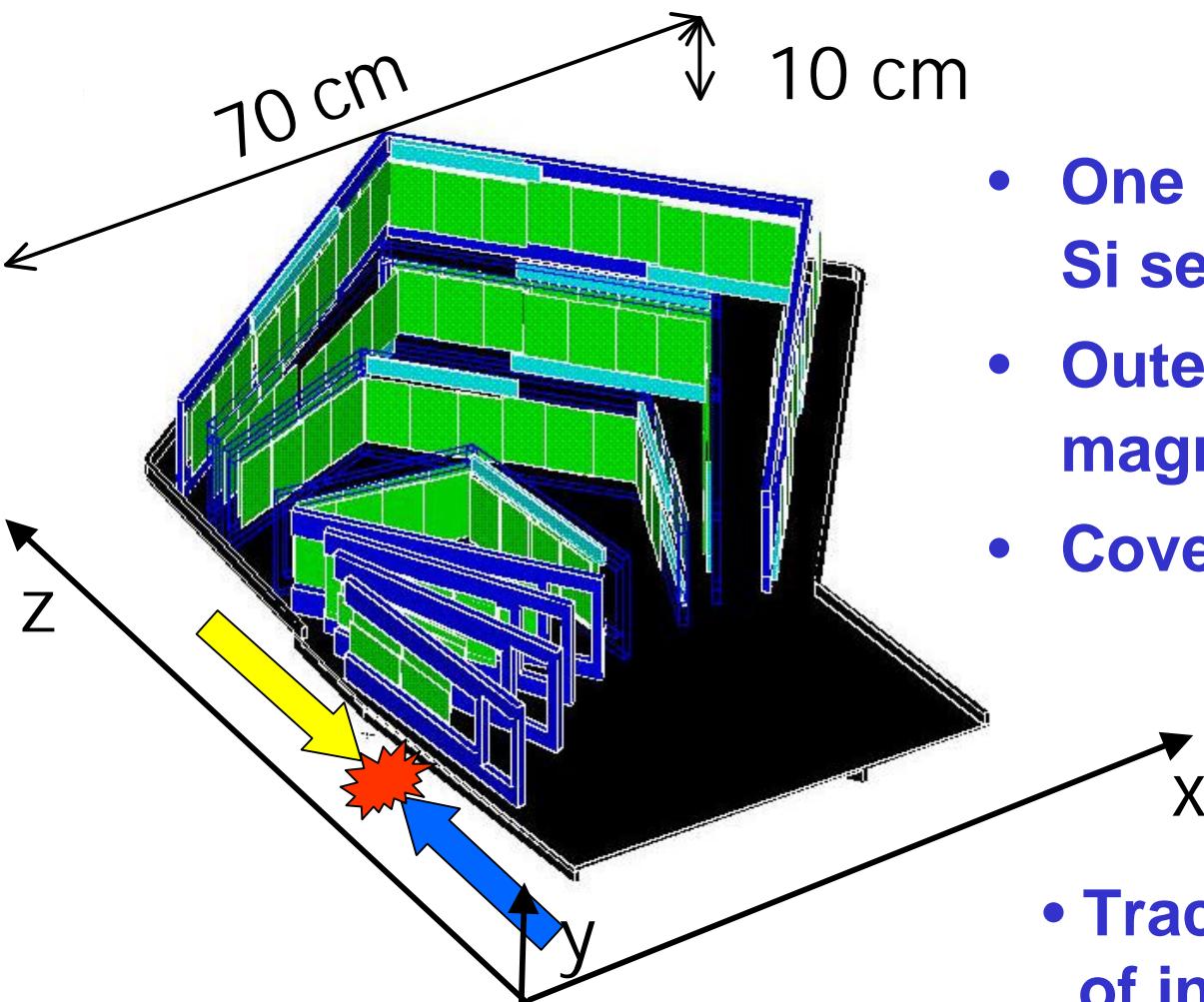


# Selecting Collisions



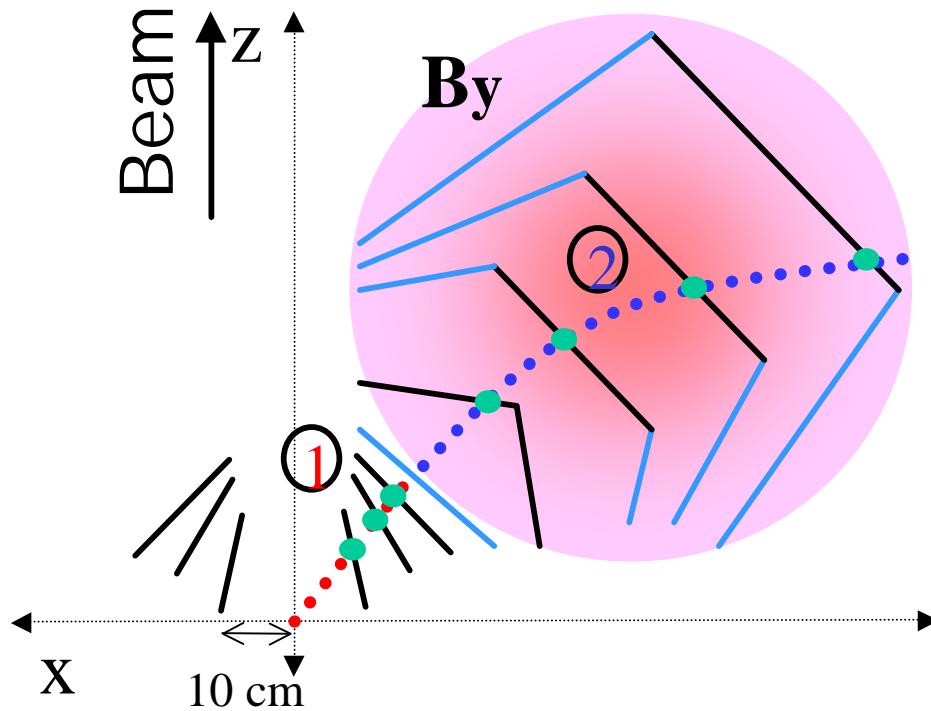
- **Coincidence between Paddle counters**
- **Paddle + ZDC timing reject background**
- **Sensitive to 97% of inelastic cross-section for Au+Au at  $\sqrt{s_{NN}} = 130 \text{ GeV}$**
- **Select 12% most central collisions**
- **Estimate  $\langle N_{\text{part}} \rangle \sim 310$**

# The PHOBOS Spectrometer



- One arm with 16 layers of Si sensors on 8 frames
- Outer layers situated in 2T magnetic field
- Coverage near mid-rapidity
- Tracking within 10cm of interaction point
- Phi acceptance 3%

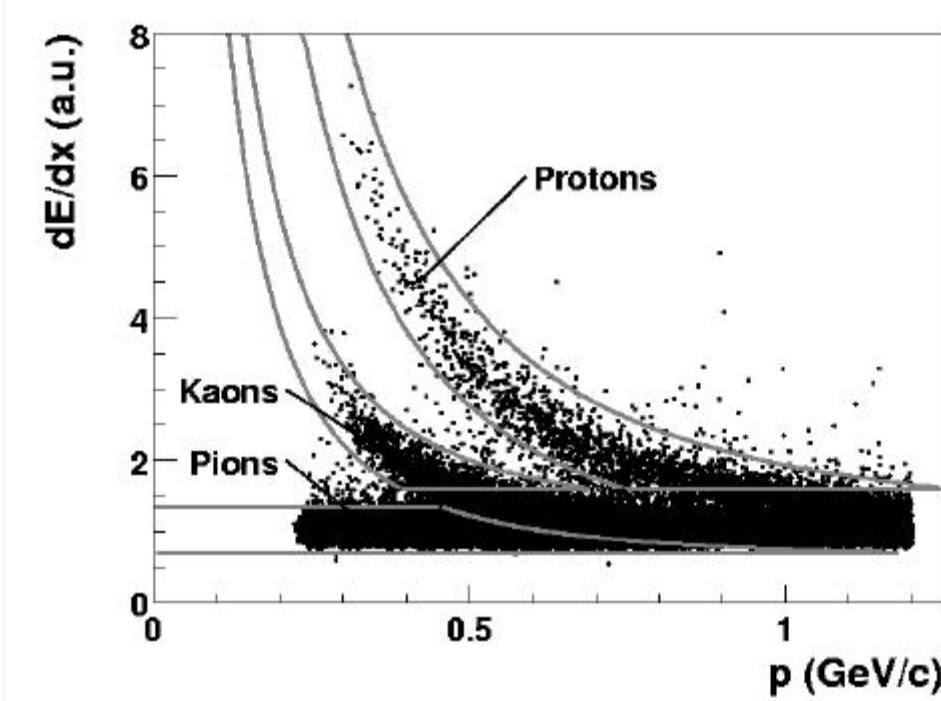
# Particle Tracking In Spectrometer



1. Road-following algorithm finds straight tracks in field-free region
2. Curved tracks in B-field found by clusters in  $(1/p, \theta)$  space
3. Match pieces by  $\theta$ , consistency in  $dE/dx$  and fit in  $yz$ -plane

- **B-field inverted to obtain antiparticle/particle ratios:**
- **e.g. Antiparticles for B+/ Particles for B-**

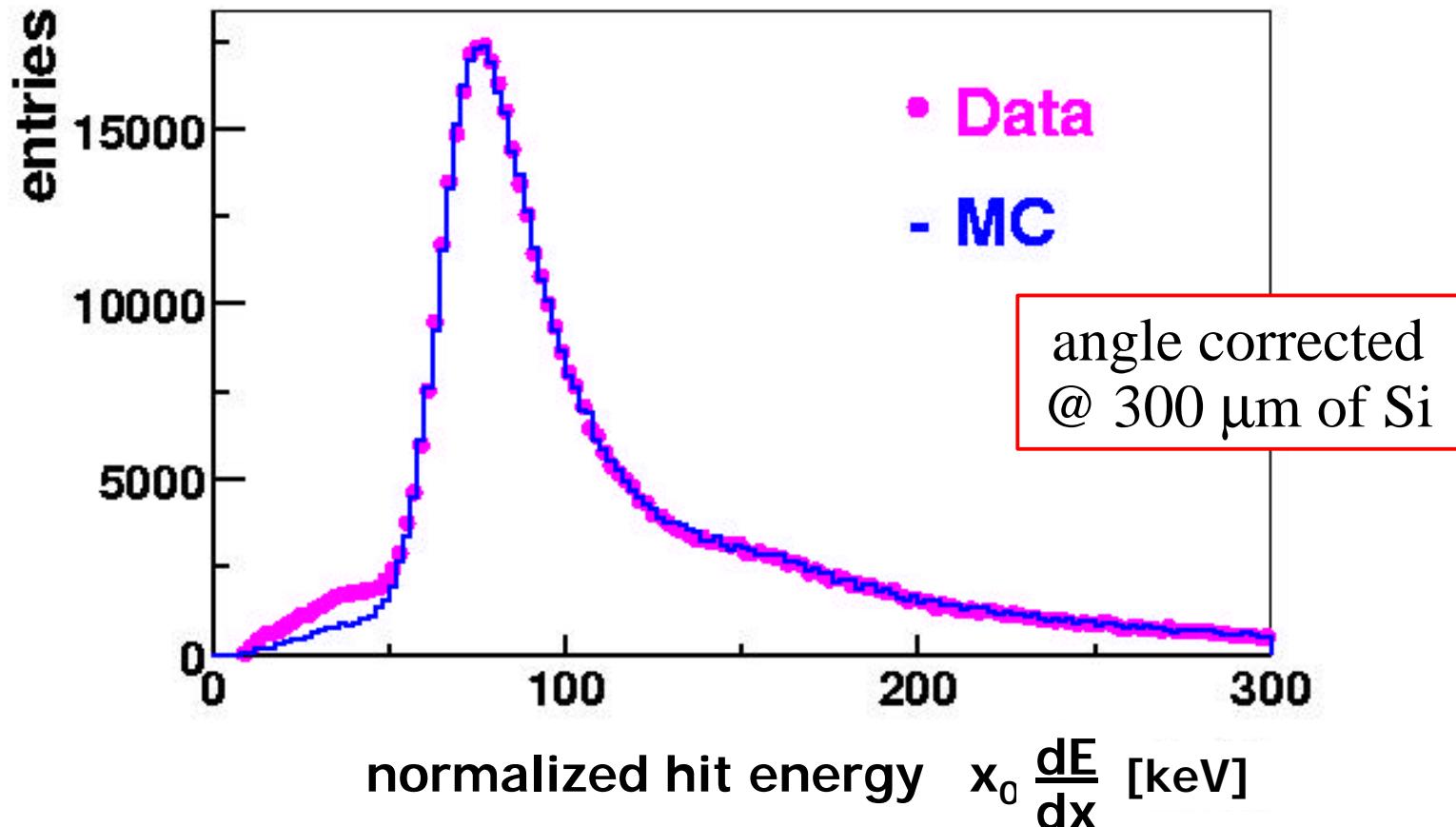
# Particle Identification



- **$dE/dx$  in Si sensors depends only on velocity**
- **$dE/dx$  vs.  $p$  therefore allows identification of particle**
- **Ratios stable w.r.t. cut variation**

# Si Signal Simulation

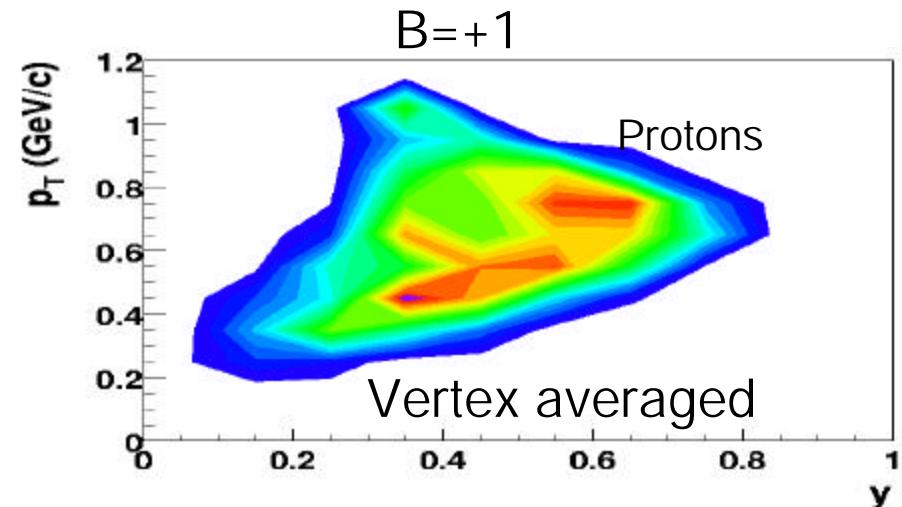
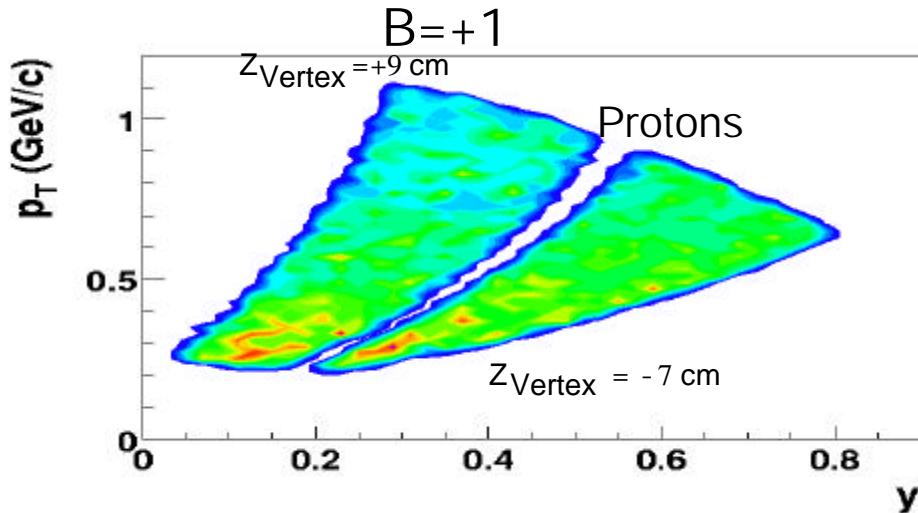
## Si signal response



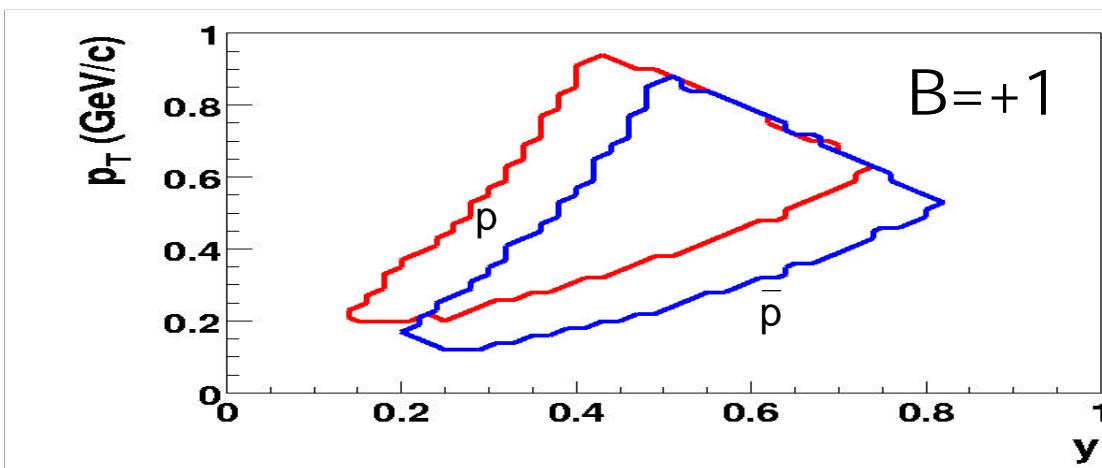
- Full understanding of detector signal at the most basic level

# Kinematic Coverage

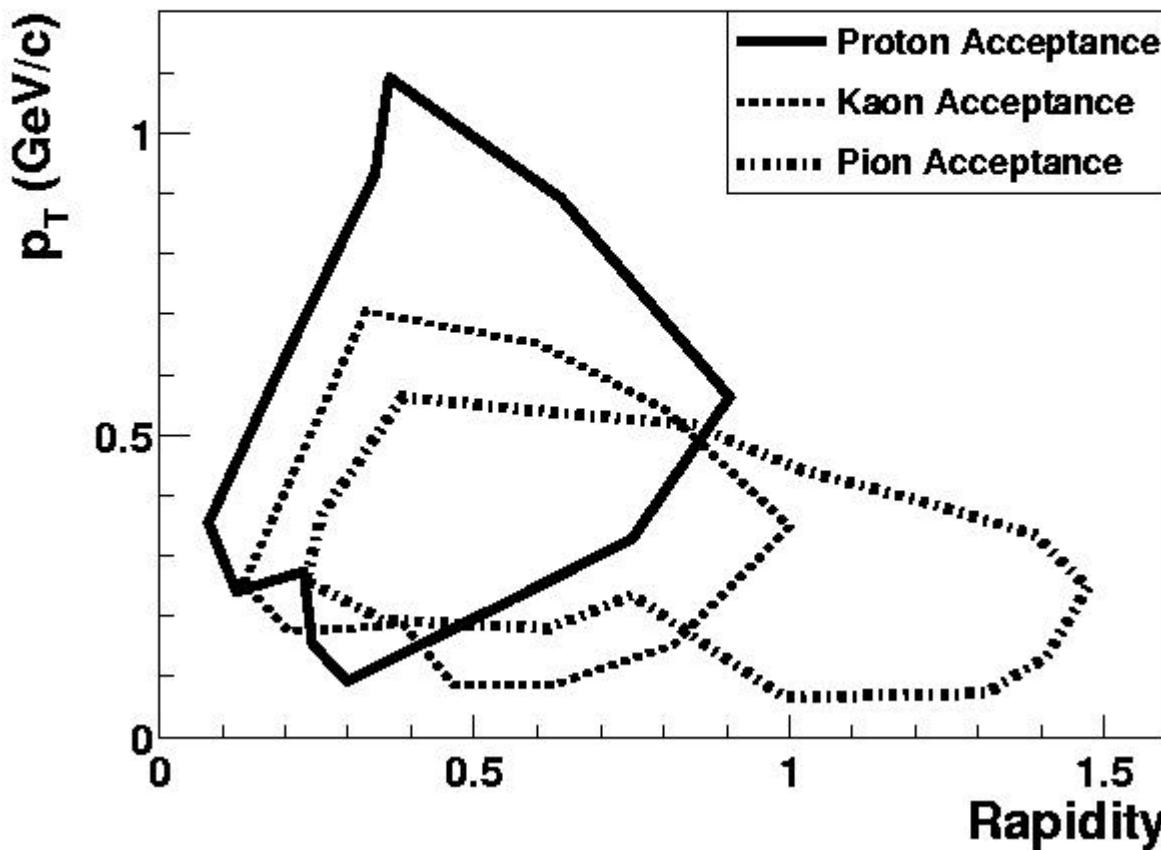
- Vertex dependent



- Charge asymmetric

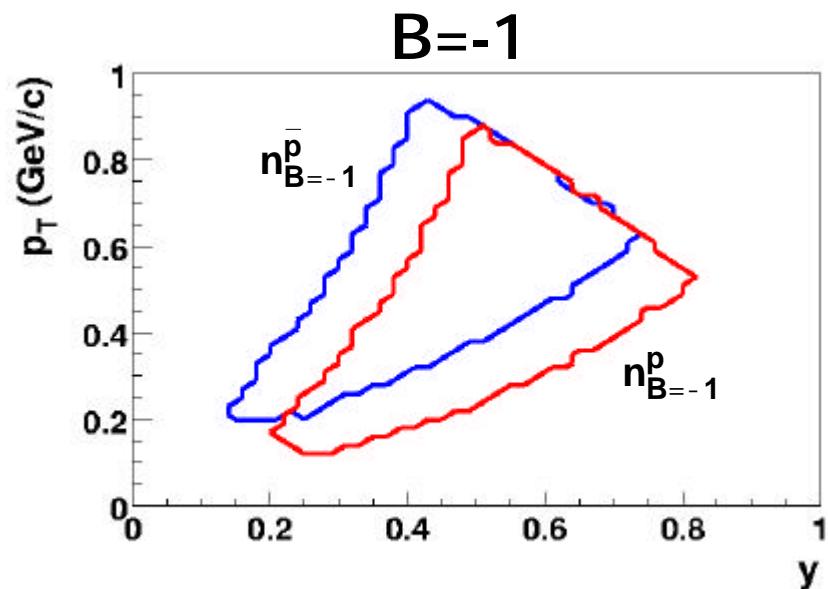
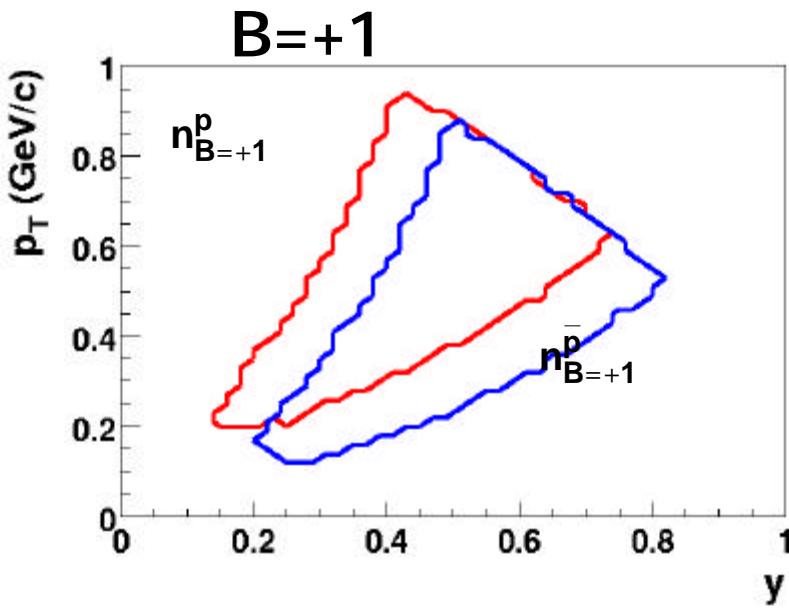


# Spectrometer Acceptance



Averaged over vertex range, azimuthal angle  
and Field Polarities

# Particle Ratio Determination



$$\frac{\left\langle E \frac{dN}{dp^3} \right\rangle_p^-}{\left\langle E \frac{dN}{dp^3} \right\rangle_p^+} = \frac{1}{2} \frac{\alpha}{\zeta} \frac{n_B^p_{B=+1}}{n_B^p_{B=-1}} + \frac{n_B^-_{B=-1}}{n_B^p_{B=+1}}$$

C<sub>Secnd.</sub> C<sub>Absorb.</sub> C<sub>Feeddown</sub>

Ratio Corrections  
(Background)

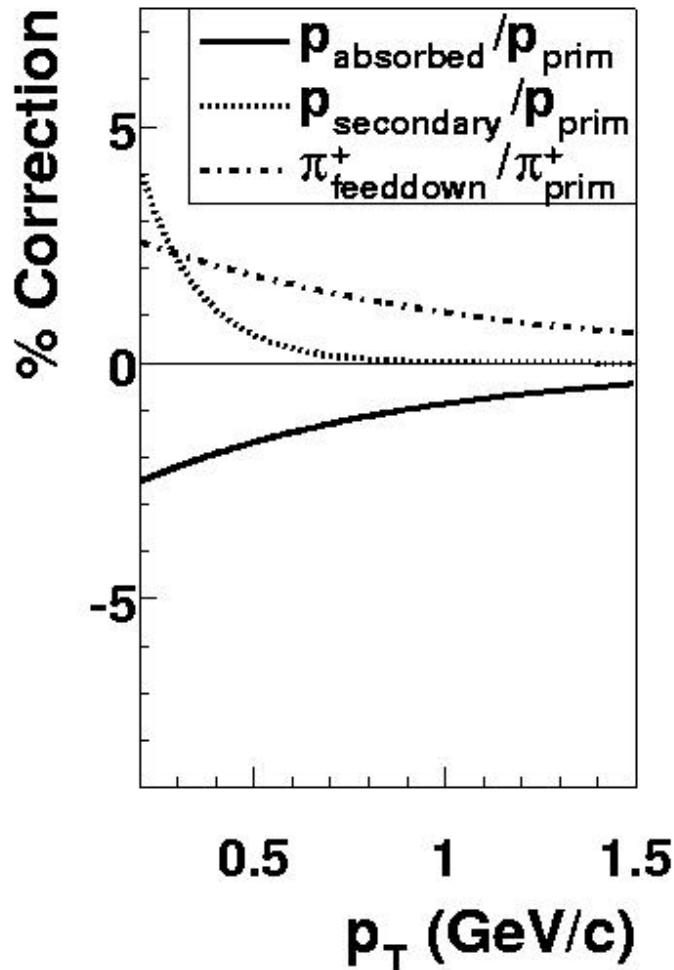
**n = number particles measured per event**

# Corrections to the Raw Numbers

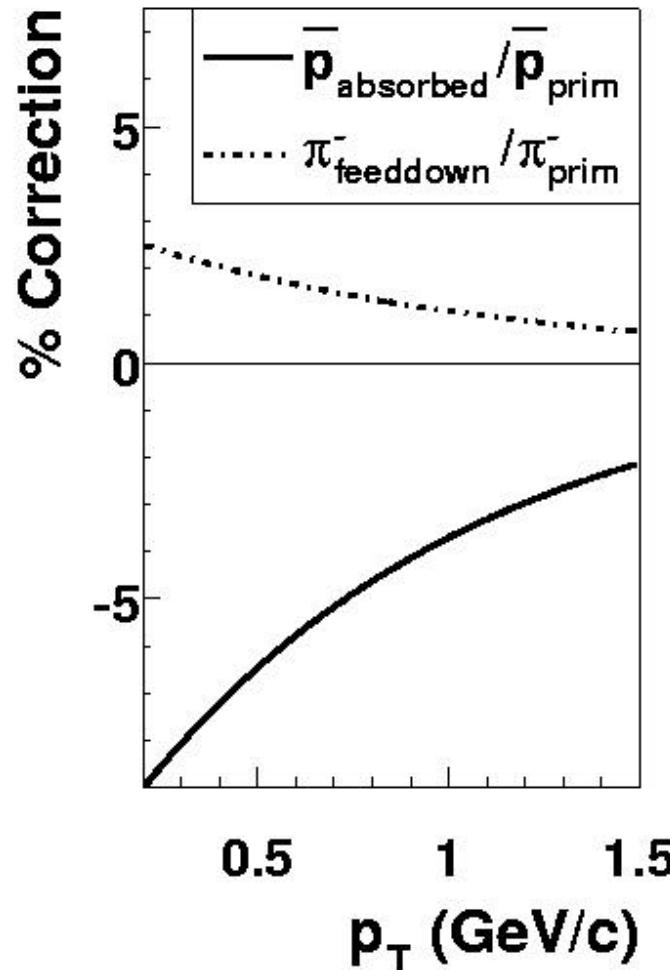
- **Secondary particles**
  - Little material between interaction point and sensitive volume => extra protons
  - +1.8% on pbar/p ratio
  - Negligible for pi and K
- **Absorption in detector**
  - From GEANT simulations
  - Loss of Anti protons
  - + 7.1% on pbar/p ratio
  - Negligible for pi and K
- **Feed-down from weak decays**
  - Reduced by tracking within 10cm of vertex
  - Further limit by a cut on the distance-of-closest-approach of the tracks to the event vertex

# $p_T$ dependence of corrections

Particles



Anti-Particles



# Correction from weak decays

- Feeddown channels:

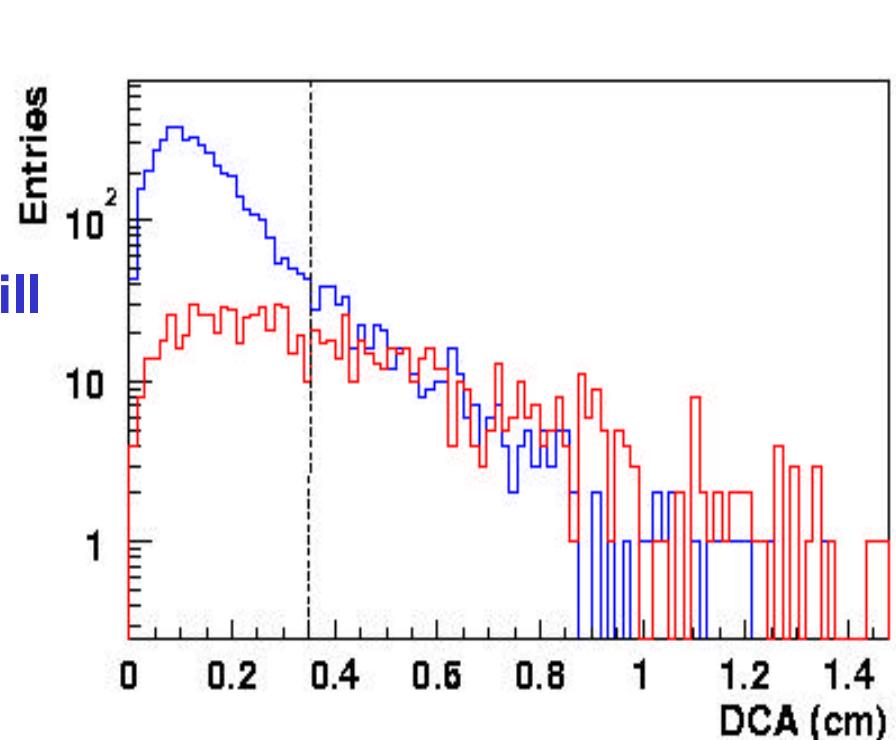
$$L \circledR pp^- \quad S^0 \circledR Lg$$

$$\bar{L} \circledR \bar{p}p^+ \quad \bar{S}^0 \circledR \bar{L}g$$

- Quark-counting suggests

$$\frac{\langle \Lambda \rangle}{\langle \bar{\Lambda} \rangle} = \frac{\langle \bar{p} \rangle}{\langle p \rangle} \times \frac{\langle K^+ \rangle}{\langle K^- \rangle}$$

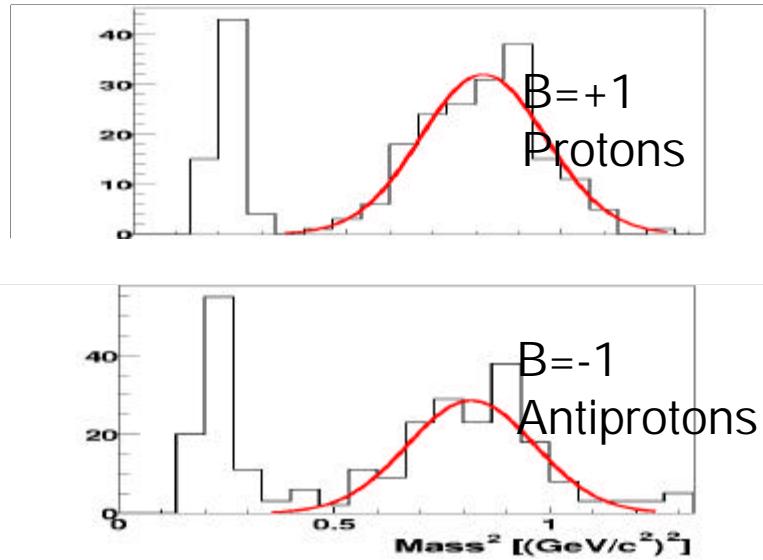
- $K^+/K^- \sim 1.1$  so  $\Lambda$  feed-down will be a small effect
- Correction depends on  $\Lambda/p$
- Tracking cuts remove 50% of feed-down Background
- Final Correction  $\sim 0\% - -3\%$  depending on  $\Lambda/p$
- Uncertainties are reflected in the systematic error



# Evidence of canceling efficiencies

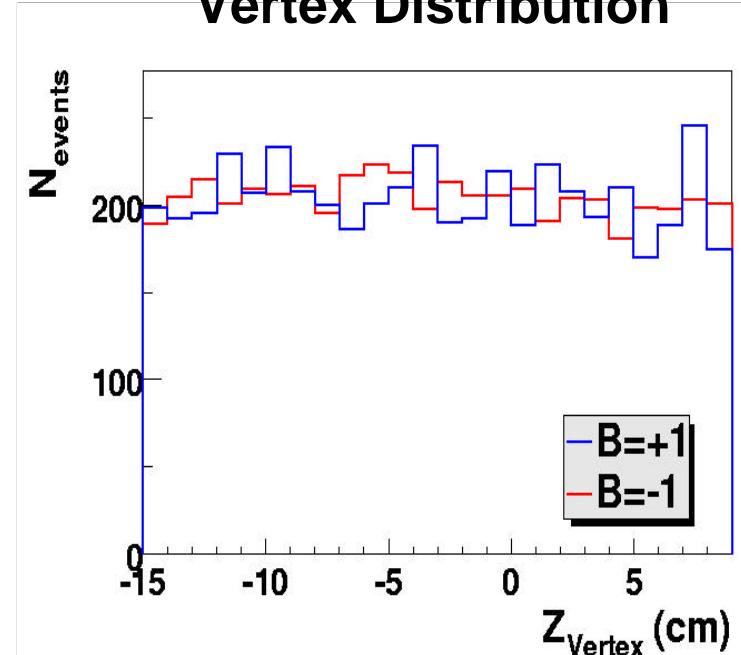
- Cut distributions same shape
- Acceptance identical

Field Strength



Mass determined using  $dE/dx$  and  $p$

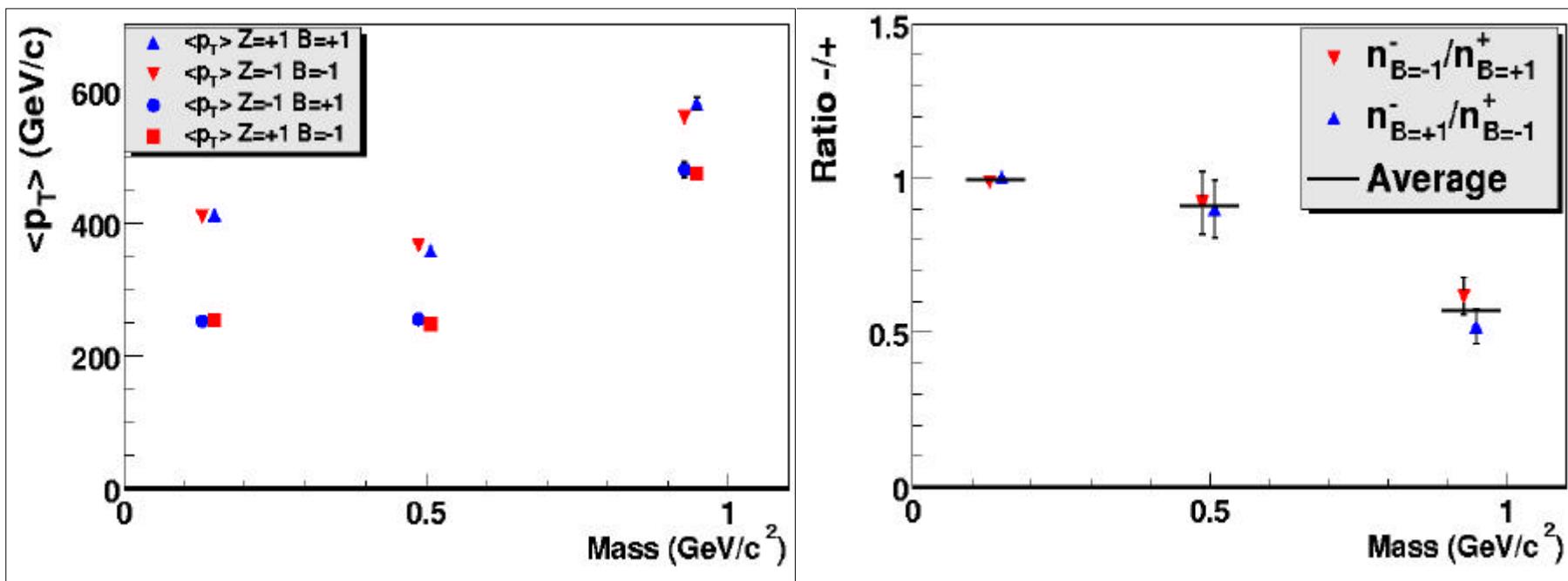
Vertex Distribution



Mass difference < 0.5%

=> Field strength same for both polarities

# Evidence of Canceling Efficiencies II



- Mean  $p_T$  distributions match
- Equality of particle ratios
- Non-canceling effects would drive ratios in opposite directions

=> meaningful interpretation of ratio

# Results

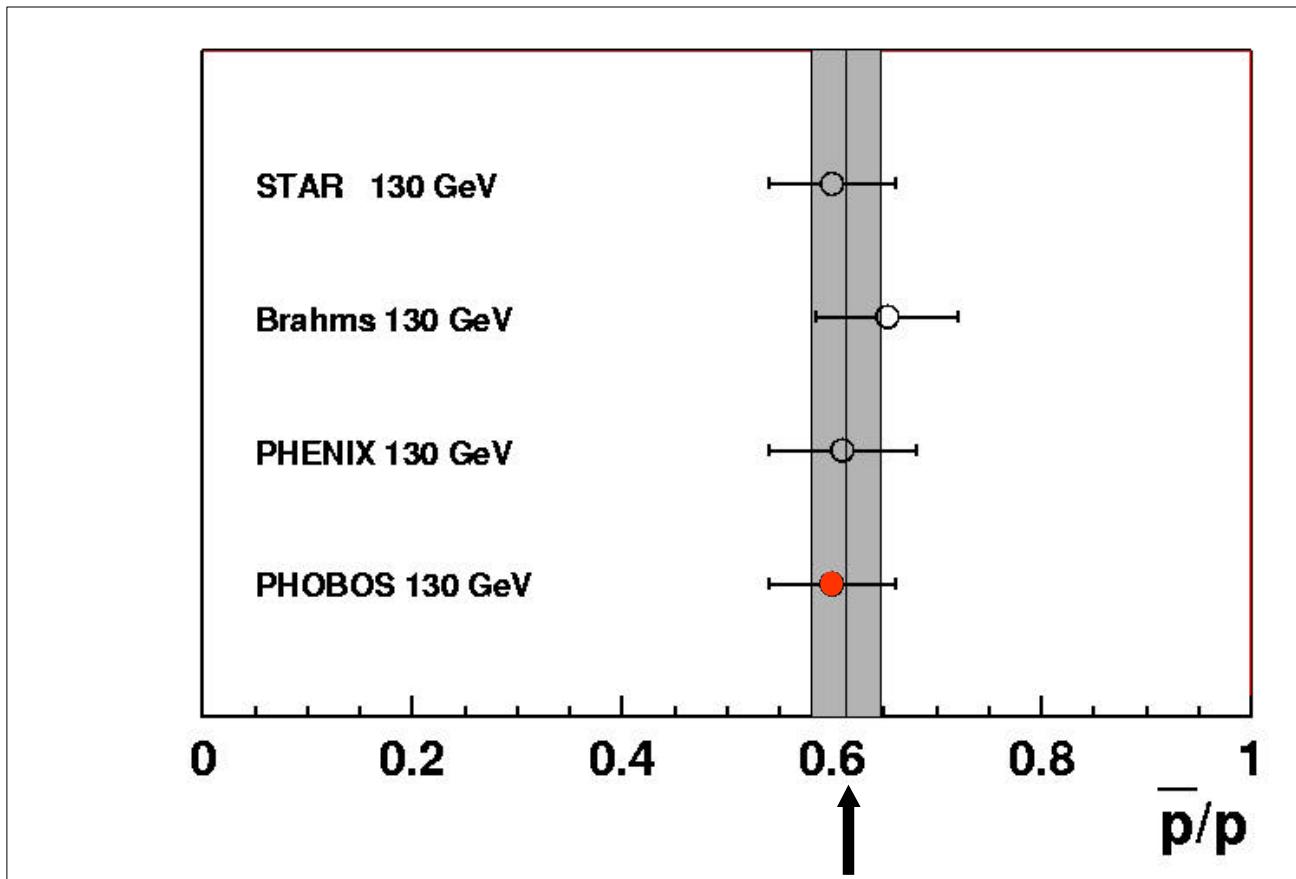
$$\frac{\langle p^- \rangle}{\langle p^+ \rangle} = 1.00 \pm 0.01(stat.) \pm 0.02(syst.)$$

$$\frac{\langle K^- \rangle}{\langle K^+ \rangle} = 0.91 \pm 0.07(stat.) \pm 0.06(syst.)$$

$$\frac{\langle \bar{p} \rangle}{\langle p \rangle} = 0.60 \pm 0.04(stat.) \pm 0.06(syst.)$$

- Publication accepted by PRL (pre-print: [hep-ex/0104032](#))

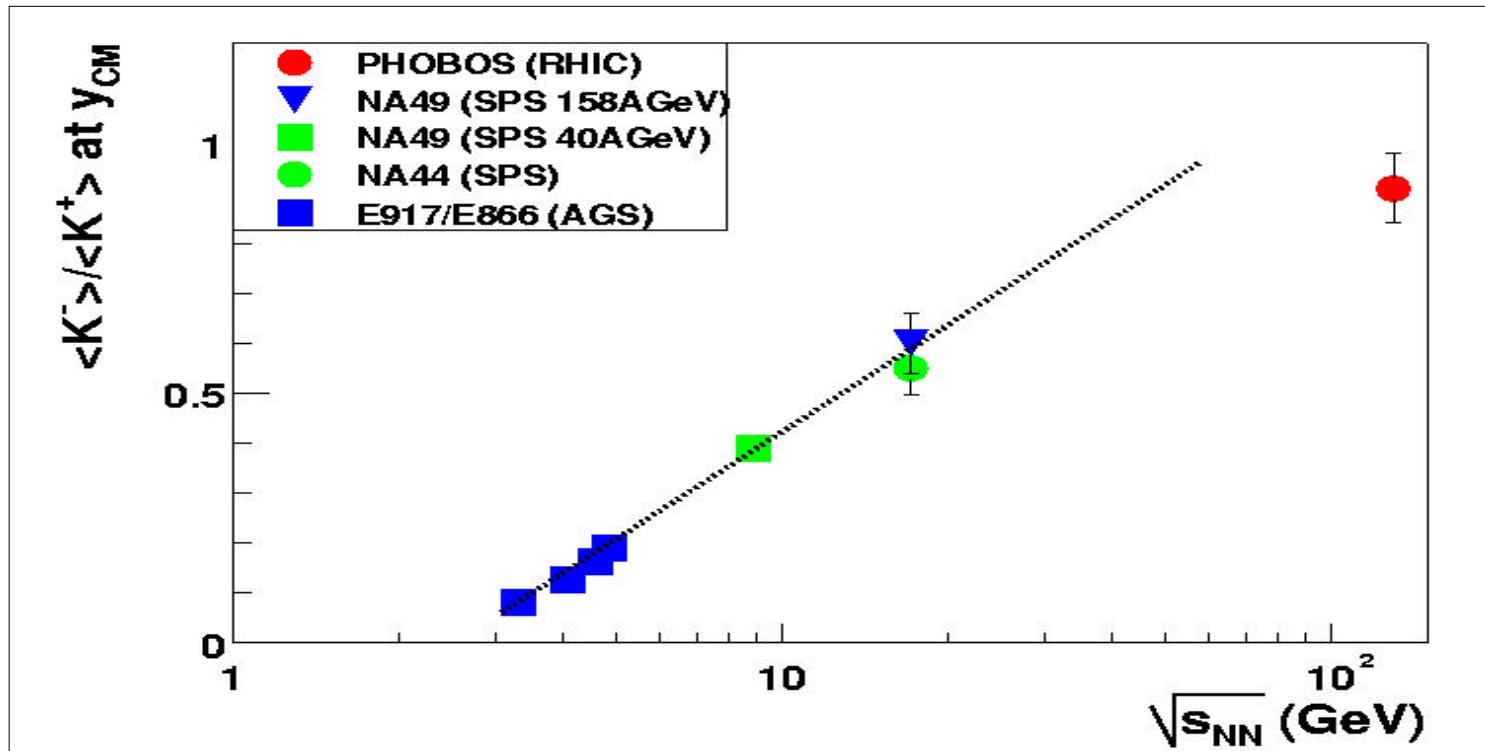
# Comparison to other Experiments



Average:  $0.61 \pm 0.03$

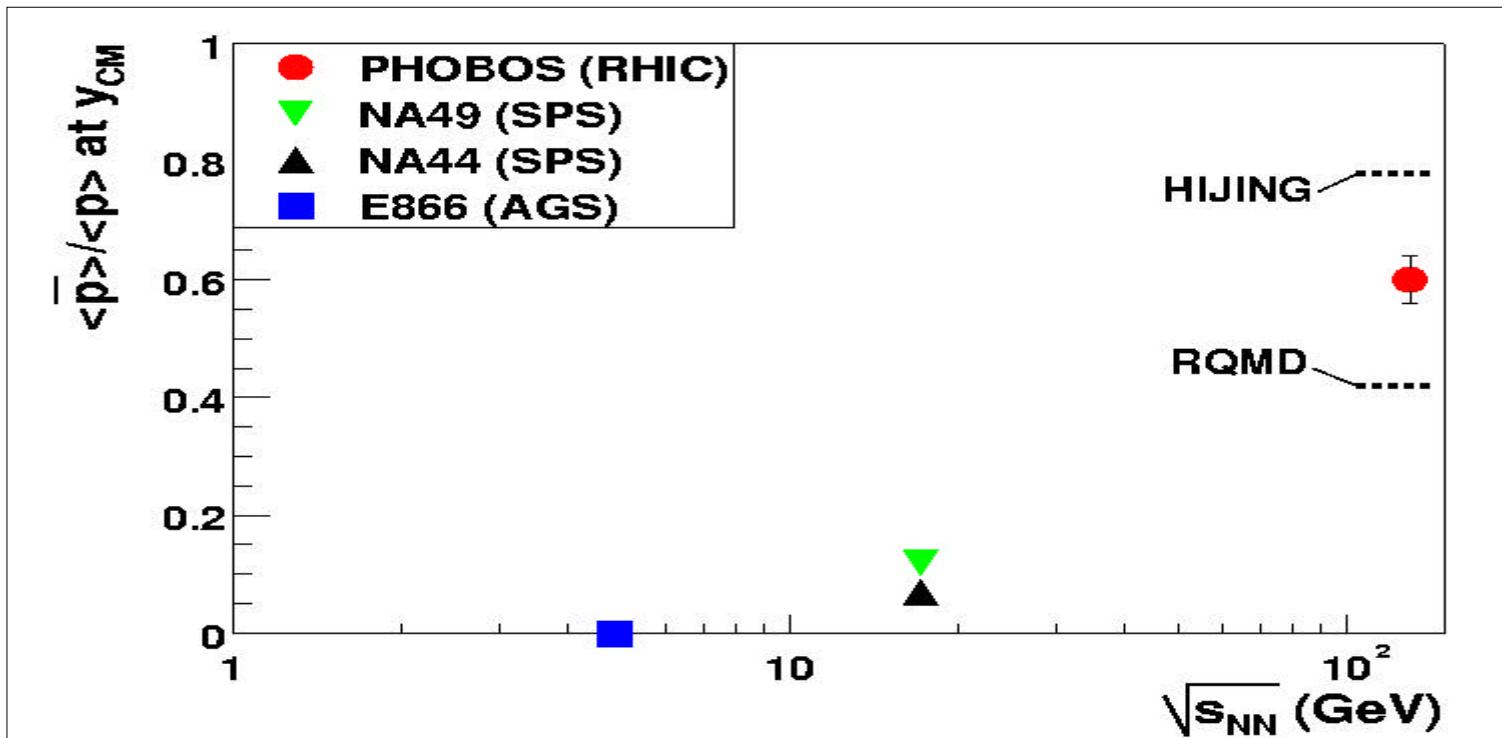
Nice agreement!

# Kaon Ratio Energy Dependence



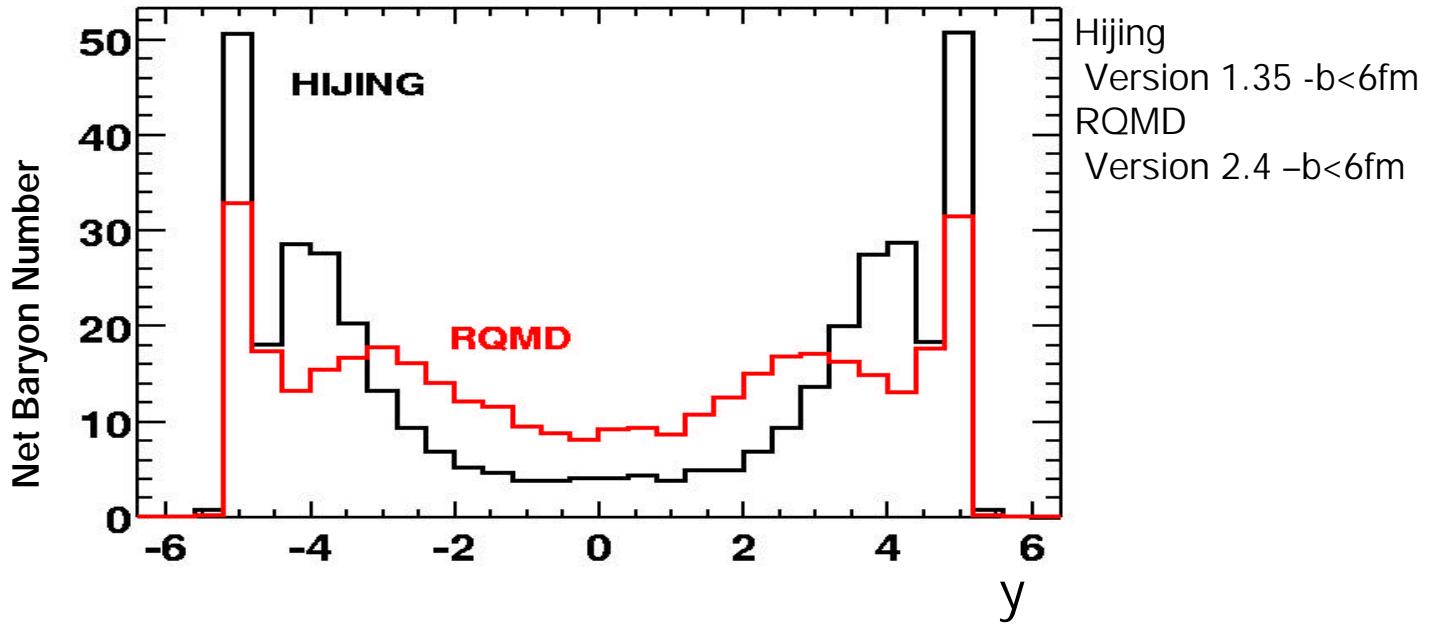
- K-/K+ significantly higher than at AGS or SPS
- Approaching unity

# Proton Ratio Energy Dependence



- $\bar{p}/p$  significantly lower than 1
- => Mid-rapidity region NOT net baryon free

# Baryon Transport

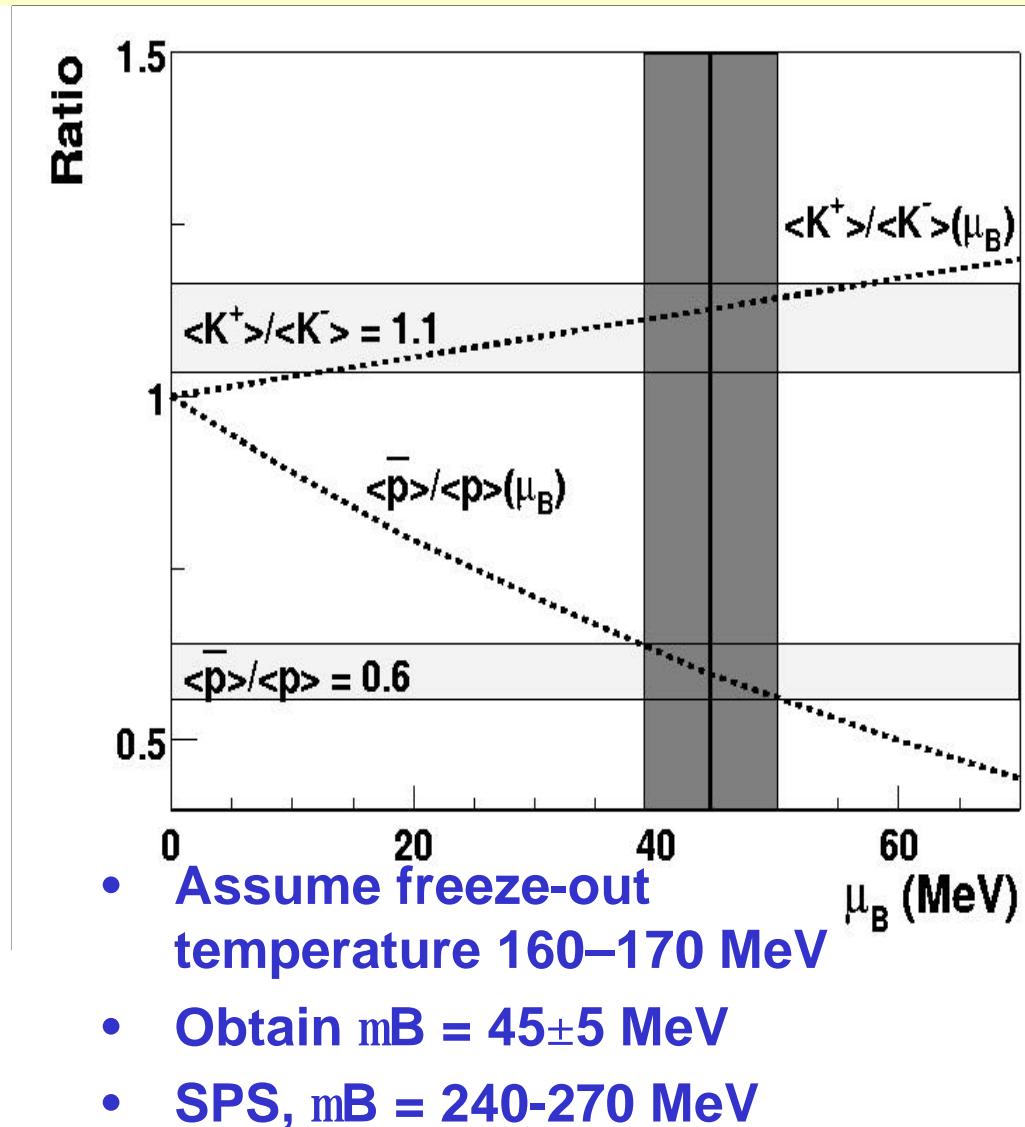


$$\left. \frac{\langle p \rangle}{\langle \bar{p} \rangle} \right|_{y \gg 0} = 0.60 +/- 0.04 \quad {}^1 \quad 1$$

- Measured ratio lies between RQMD and Hijing.  
Each has different baryon stopping.

# Thermal Model Interpretation

- Ratios sensitive to baryon chemical potential  
 $p/\bar{p} \sim \exp(2m_B/T)$
- We have adapted model from Redlich, et al presented at QM2001
- Single  $m_B$  matches both proton and kaon ratios!
- Much lower than SPS!



# Summary I

For central Au + Au Collisions @  $\sqrt{s} = 130 \text{ GeV}$ :

- Antiparticle/particle ratios measured near mid-rapidity by PHOBOS silicon spectrometer
- K-/K+ and pbar/p higher than at AGS or SPS
- pbar/p consistent with non-zero net baryon density at mid-rapidity
- mB=45 MeV for typical freeze out Temp. (~170MeV)

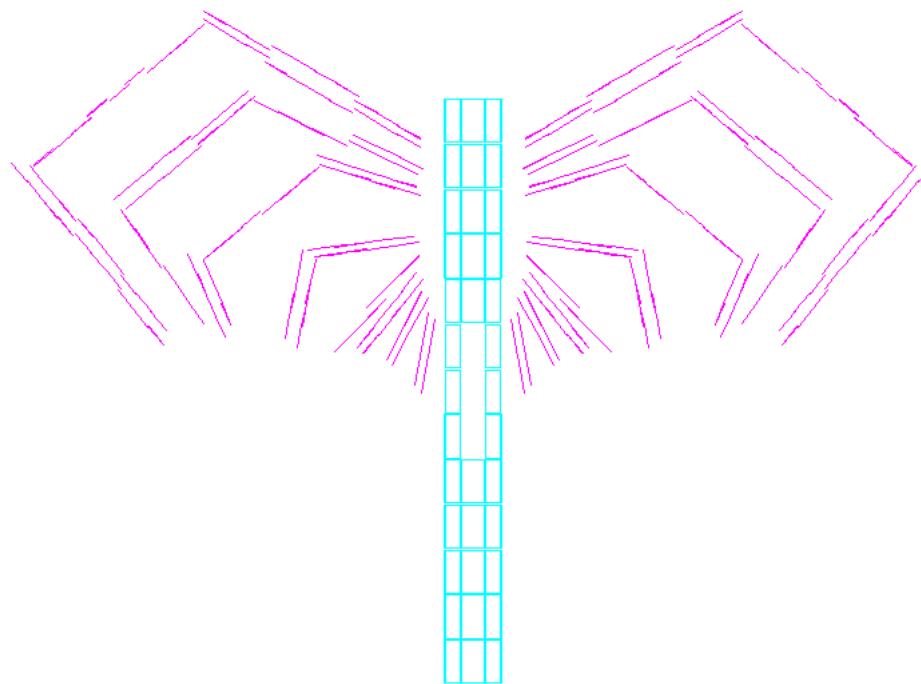
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$$\frac{\langle \bar{p} \rangle}{\langle p \rangle} = 0.60 \pm 0.04(\text{stat.}) \pm 0.06(\text{syst.})$$

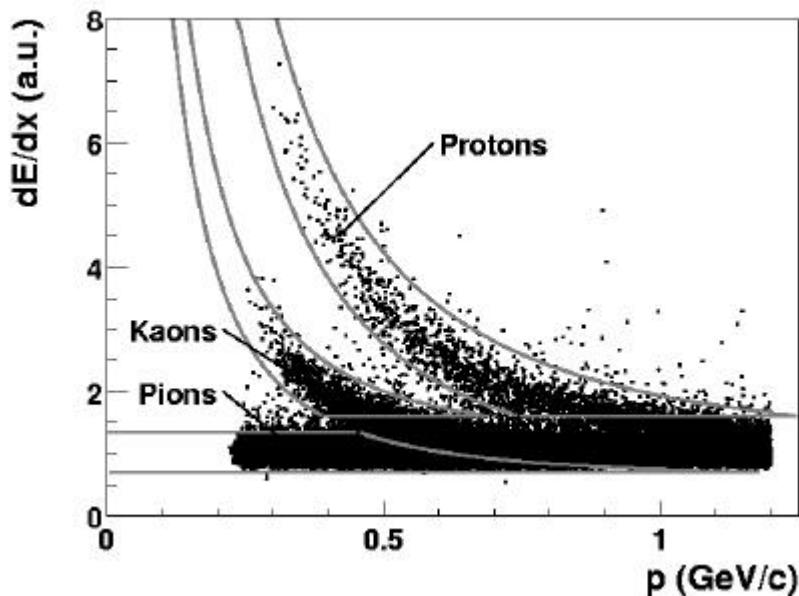
# Outlook I : 2001

**Full detector installed!**

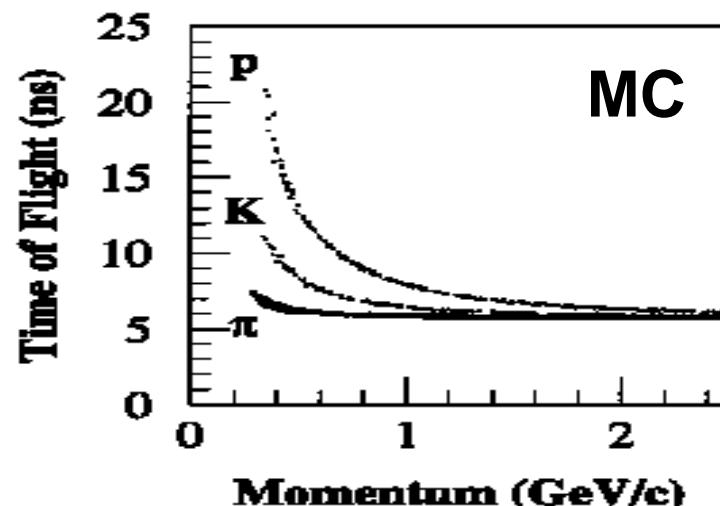


# I dentified Particle Spectra 2001

## dE/dx – Identification:



## TOF – Identification:



- Analysis of 130GeV data  
In Progress
- Acceptance
  - dE/dx Resolution 7.5%
  - Pions  $100 < p_T < 600 \text{ MeV}$
  - Kaons  $200 < p_T < 700 \text{ MeV}$
  - Protons  $200 < p_T < 1000 \text{ MeV}$

- TOF commissioned in PR01.
- Will approx. double PID range

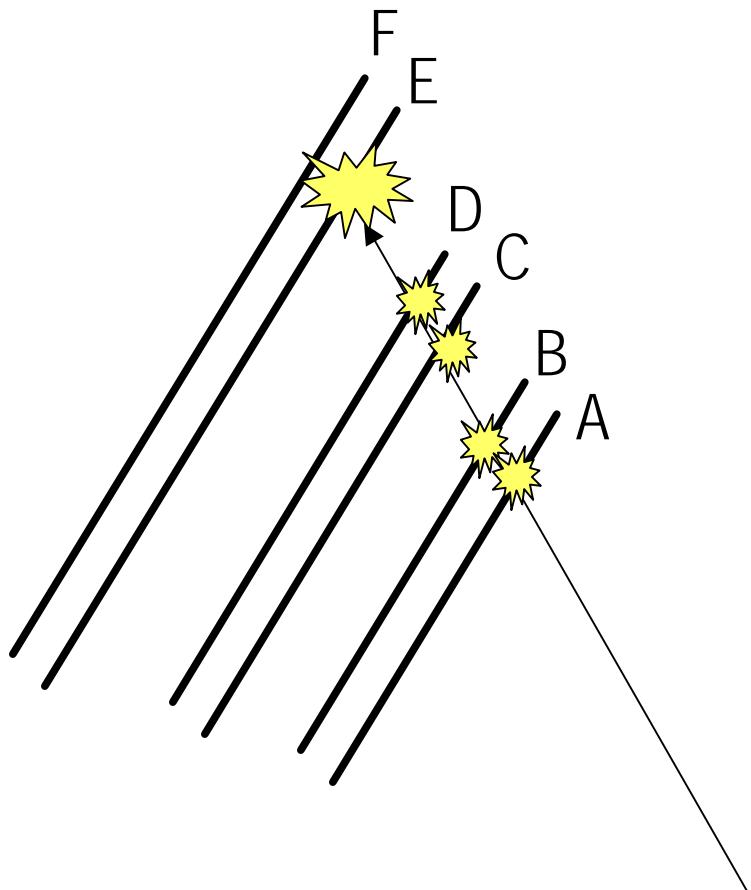
# Measurement of slow particles

- Use straight silicon planes
  - look for stopping particles!
- For each track that stops in 5<sup>th</sup> plane, calculate:

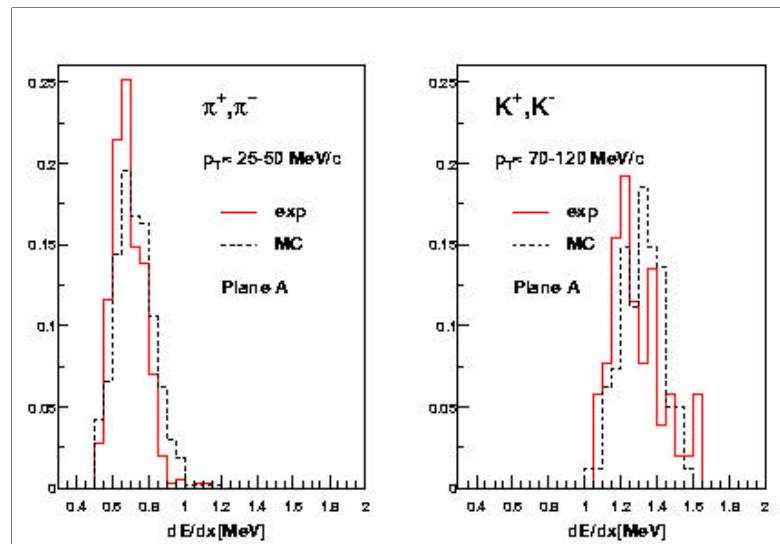
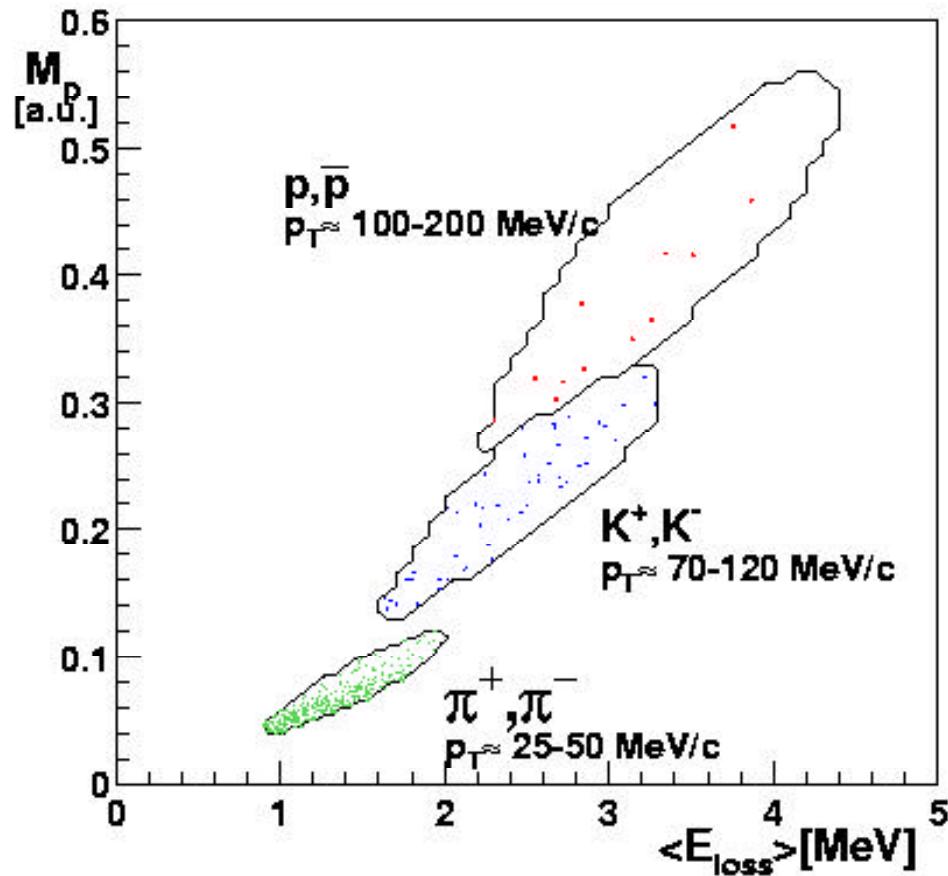
$$M = \sum_i \frac{dE}{dx} \Big|_i \times E_i^{loss}$$

Loss in plane i              Total loss from i to E

$$\langle E_{loss} \rangle = \sum_i \Delta E_i / N_{hits}$$

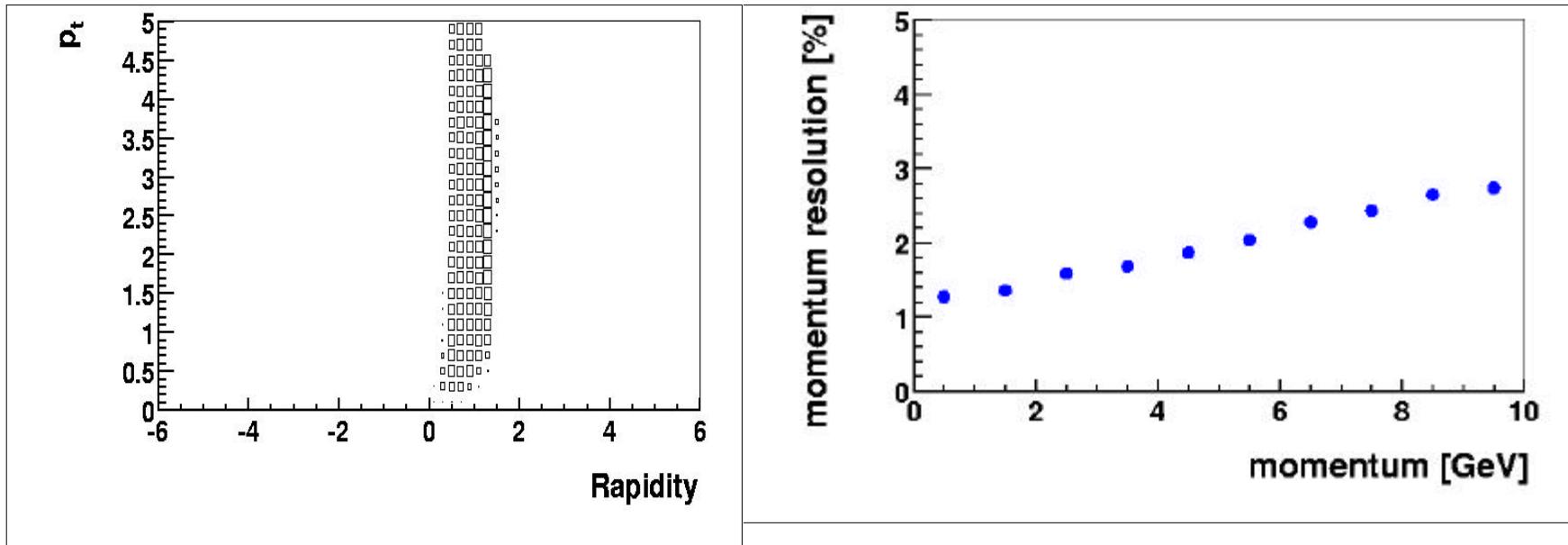


# Low- $p_T$ particles: Data vs. MC



- Good agreement between Data and MC (HIJING)
- Good control over energy scale and resolution
- Lots of work to extract spectra
- Access to low- $p_T$  sector of hadron spectra

# Charged Particle Spectra 2001



- Good momentum resolution up to very high momenta
- Charged particle spectra  $p_t$  range only limited by available statistics

# Finale...

*July 18, 2001*

*00:48:41*



*Run 7224*

*Event 5261*

